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EFFECTS OF WITHIN-CLASS DIFFERENCES IN SAMPLE RESPONDING ON ACQUIRED SAMPLE EQUIVALENCE

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Two experiments examined whether acquired sample equivalence in many-to-one matching was affected by variation in sample–response requirements. In each experiment, pigeons responded on either identical or different response schedules to the sample stimuli that occasioned the same reinforced comparison choice (i.e., to the within-class samples). Transfer-of-control tests were then conducted to determine acquired equivalence, or lack thereof, between these samples. In both experiments, there was minimal or no evidence of acquired sample equivalence when pigeons responded differently to the samples within each common-choice class. By contrast, transfer was observed if pigeons responded (a) identically to all sample stimuli, or (b) identically to samples within each common-choice class (viz., to samples that occasioned the same reinforced choice) and differently to samples from different classes (viz., to samples that occasioned different choices). These results may help to explain the recent lack of evidence for response membership in pigeons' acquired equivalence (Urcuioli, Lionello-DeNolf, Michalek, & Vasconcelos, 2006). They also raise questions about the functional sample stimuli and about possible interactions between acquired equivalence and acquired distinctiveness.

Key words: acquired equivalence, many-to-one matching, sample responding, transfer tests, functional stimuli, pigeons, pecking

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The many demonstrations of acquired equivalence and other forms of categorization using nonhuman animals (e.g., Bhatt, Wasserman, Reynolds, & Knauss, 1988; Bovet & Vauclair, 1998; Cook, Katz, & Cavoto, 1997; Edwards, Jagielo, Zentall, & Hogan, 1982; Honey & Hall, 1989; Schusterman, Reichmuth, & Kastak, 2000; Urcuioli, Zentall, Jackson-Smith, & Steirn, 1989) show that complex, ostensibly higher-order behavior likely reflects basic processes common to many species. Indeed, this belief has fostered wide-ranging lines of research as exemplified in Wasserman and Zentall's recent (2006) collection of chapters on comparative cognition.

More narrowly, the literature on acquired equivalence in nonhuman animals raises questions about how this phenomenon is related to the extensively studied, highly analyzed phenomenon of stimulus equivalence in humans (Dougher & Markham, 1994; Saunders, Williams, & Spradlin, 1996; Sidman, 1994). Although there has been healthy debate about the relation between these two phenomena and about the possibility of a human/nonhuman division in stimulus equivalence (see, for example, Dube, McIlvane, Callahan, & Stoddard, 1993; Frank & Wasserman, 2005a; Hayes, 1989; Sidman, 2000; Vaughan, 1988, 1989; see also Horne & Lowe, 1996), there is no debate that these phenomena demonstrate that new behavior and new stimulus control relations can emerge from training in ways not explicable by primary stimulus generalization (Honig & Urcuioli, 1981). Furthermore, experiments with nonhuman animals permit another avenue for testing hypotheses about the nature and origins of equivalence classes in general (Sidman, 2000).

For instance, in a recent series of experiments with pigeons, Urcuioli, Lionello-DeNolf, Michalek, and Vasconcelos (2006) tested Sidman's (2000) contention that equivalence relations can also include reinforcers and responses if they, too, are differential with respect to the task contingencies. Specifically, Urcuioli et al. asked if different sample–response patterns would join functional (or acquired) equivalence classes that typically arise from training on many-to-one (MTO) matching (Urcuioli et al., 1989; Urcuioli &

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Lionello-DeNolf, 2001) if each individual pattern occasioned the same reinforced comparison choice as another, visual sample stimulus. Such an outcome would certainly seem to be implied by Sidman's (2000) theoretical position.

To test the prediction, Urcuioli et al. (2006, Experiments 1 and 2) arranged that a distinctive hue sample (e.g., red) to which pigeons pecked once, and a white center-key stimulus to which they completed a differential-reinforcement-of-low-rates-of-responding (DRL) schedule, both occasioned one reinforced choice; whereas a different hue sample (e.g., green) to which pigeons pecked once, and a white center-key stimulus to which they completed a fixed-ratio (FR) schedule, both occasioned the alternative reinforced choice. After acquiring this MTO task to high levels of accuracy, pigeons then learned a second, ''reassignment'' task (cf. Wasserman, deVolder, & Coppage, 1992) in which either the two response patterns or the two hue samples were established as conditional cues for new comparison choices. Finally, the ability of the remaining samples to cue those new choices was tested. The prediction was that if MTO training produced acquired equivalence between sample–response patterns and visual samples that occasioned the same reinforced choice, these class elements should also be interchangeable with one another in new contexts (i.e., in testing). In other words, each sample appearing in testing should immediately occasion the same comparison choice that its common-choice sample counterpart had occasioned during reassignment training (cf. Goldiamond, 1962).

However, the transfer effect did not materialize in these experiments or in a conceptually similar one (Urcuioli et al., 2006, Experiment 4) that used a multiple rather than a mixed schedule to generate the DRL vs. FR sample–response patterns during MTO training. The negative findings were surprising for two reasons. First, they contrasted with transfer results indicative of acquired equivalence typically obtained from pigeons after MTO training. Second, separate experiments independently confirmed that the DRL vs. FR sample–response patterns had, in fact, cued the pigeons' comparison choices (cf. Urcuioli et al. 2006, Experiments 3 and 5; see also Urcuioli & Honig, 1980). Nevertheless, the results disconfirmed the hypothesis of response membership in acquired equivalence classes, and they led to the present experiments which were designed to determine why those results were obtained.

In view of previous studies showing that pigeons can be rather literal creatures (e.g., for them, the same stimulus appearing in different locations is a functionally different stimulus—see Lionello and Urcuioli, 1998), we surmised that stimuli to which pigeons peck multiple times (e.g., on a DRL or FR schedule) are functionally different than stimuli to which they peck only once. Consequently, even though white pecked on a DRL schedule and red pecked once were conditional cues for the same reinforced choice in Urcuioli et al. (2006, Experiments 1 and 2), this response difference may have precluded an acquired equivalence between them. Likewise, although white pecked on a FR schedule and green pecked once were conditional cues for the same alternative choice, this difference may have had the same inhibiting effect. Moreover, the situation may have been exacerbated because in addition to these within-class differences, the MTO tasks used by Urcuioli et al. (2006) also involved between-class similarities in responding. In other words, pigeons responded in a similar fashion to samples occasioning *different* reinforced choices (e.g., once to red and once to green, and multiple times on both DRL and FR trials).

Interestingly, nearly all demonstrations of acquired sample equivalence in pigeons (e.g., Astley & Wasserman, 1999; Urcuioli et al., 1989; Urcuioli & Lionello-DeNolf, 2001, 2005; Urcuioli, Zentall, & DeMarse, 1995; Wasserman et al., 1992) have come from studies involving matching tasks with identical sample–response requirements for all samples. Thus, it could be that the negative results reported by Urcuioli et al. (2006) do not reflect limitations on membership in an acquired equivalence class but, instead, the within-class differences and between-class similarities in sample responding mentioned above. If so, then we should also find no evidence of acquired sample equivalence after training on a typical (i.e., all-visual-sample) MTO task if sample–response requirements are varied in a manner that mimics these differences and similarities.

Table 1

Schematic of the Many-to-One Contingencies in Experiment 1.

Differential	Nondiff-Within	All-FR
S1 • DRL → C1+	S1 • FR → C1+	S1 • FR → C1+
S2 • FR → C2+	S2 • FR → C2+	S2 • FR → C2+
S3 • CRF → C1+	S3 • CRF → C1+	S3 • FR → C1+
S4 • CRF → C2+	S4 • CRF → C2+	S4 • FR → C2+

Note. S1–S4 represent sample stimuli; C1 and C2 represent comparison stimuli, (+) = reinforced comparison choice, DRL= differential-reinforcement-of-low-rates-of-responding schedule, FR = fixed ratio schedule, CRF = continuous reinforcement schedule. DRL and FR schedule parameters and nonreinforced comparison choices are not shown.

This hypothesis guided the present experiments. In each, pigeons initially learned MTO matching with hues and lines of different orientations serving as the nominal sample stimuli. For all groups, one hue and one line occasioned one reinforced comparison choice, and the other hue and the other line occasioned the alternative reinforced choice. Groups differed from one another in their sample–response requirements. For some pigeons, the same requirement was in effect for samples that occasioned the same reinforced choice (viz., for the ''within-class'' samples) whereas for others, different requirements were in effect. We predicted that transfer tests following a subsequent reassignment phase would reveal acquired sample equivalence with the former type of sample–response training but not after the latter.

EXPERIMENT 1

Experiment 1 consisted of three MTO training conditions (see Table 1), all of which involved four visually distinct center-key sample stimuli (S1 – S4) and two comparison alternatives (C1 and C2). Pigeons in the Differential group were trained in the same fashion as the pigeons in Urcuioli et al. (2006, Experiment 4). On matching trials with samples from one visual dimension (e.g., line orientation), they obtained the comparisons by pecking one sample (S1—e.g., vertical lines) on a DRL schedule and the other (S2—e.g., horizontal lines) on a FR schedule. On matching trials with samples from an orthogonal visual dimension (S3 and S4—e.g., red and green hues), they obtained the comparisons by pecking each sample once (i.e., on a continuous reinforcement schedule, or CRF). Note that the response requirements differed for samples occasioning the same reinforced choice but were identical or similar for samples occasioning different reinforced choices. For instance, for the two samples (S1 and S3) that occasioned the C1 choice, pigeons completed a DRL requirement to one but a CRF requirement to the other. Likewise, for the two samples (S2 and S4) that occasioned the C2 choice, pigeons completed a FR requirement to one but a CRF requirement to the other. On the other hand, they pecked once to both S3 and S4 each of which occasioned different reinforced choices, and they pecked multiple times to both S1 and S2, each of which also occasioned different reinforced choices. Despite the use of DRL vs. FR requirements for this group, we were not interested in, nor did we explicitly test for, response membership in acquired equivalence classes (Sidman, 2000). Rather, our concern was an assessment of acquired equivalence involving the S1 and S2, and S3 and S4, samples.

Group Nondiff-Within received training similar to that for Group Differential: different response requirements were scheduled for samples occasioning the same reinforced choice (e.g., FR to S1 but CRF to S3) and identical requirements were scheduled for samples occasioning different choices (viz., FR to both S1 and S2, and CRF to both S3 and S4). For these pigeons, sample–response requirements were nondifferential within both the line (S1–S2) and hue (S3–S4) dimensions. This group was of particular interest to our working hypothesis because their contingencies insured that comparison choices could not be guided by differential (FR vs. CRF) sample responding. Instead, choices had to be cued (at least in part) by the samples themselves.

Finally, Group All-FR was trained on a MTO task that typically yields acquired sample equivalence. Pigeons in this control group completed the same FR requirement to all samples. Their training, then, did not involve scheduled differences in responding to the samples that occasioned a common reinforced choice.

Following MTO acquisition, acquired sample equivalence was assessed in each group by transfer-of-control tests (not shown in Table 1). These tests evaluated the ability of the line samples (S1 and S2) to immediately occasion new comparison choices following interim reassignment training during which the hue samples (S3 and S4) were established as conditional cues for those new choices. We predicted transfer in Group All-FR, but not in Groups Differential and Nondiff-Within.

Method

Subjects

Eighteen experimentally naïve White Carneaux pigeons (*Columba livia*) began the experiment. All were retired breeders obtained from the Palmetto Pigeon Plant (Sumter, SC) and were housed individually in stainless-steel, wire-mesh cages in a colony room on a 14h/10h day/night cycle (lights on at 07:00). They were gradually reduced to and maintained at 80% of their free-feeding body weights by restricted feeding. During the experiment, feeding was generally confined to the experimental sessions. Home-cage feeding occurred only when sessions were not run or after sessions in which pigeons obtained insufficient food to maintain 80% body weights. Grit and water was freely available in the home cages.

One pigeon in Group Nondiff-Within was dropped from the experiment during reassignment training because of failure to learn; it was not replaced. One Group Differential bird was dropped due to experimenter error and another due to inability to meet the performance criterion during MTO training. The latter birds were replaced by other experimentally naïve pigeons.

Apparatus

The experiment was run in two BRS/LVE (Laurel, MD) three-key pigeon chambers (Model PIP-016 panels inside Model SEC-004 enclosures). The interior dimensions of each chamber, outlay of the panels, ventilation, etc. are described in detail elsewhere (e.g., Urcuioli et al. 2006). The in-line stimulus projector (BRS/LVE Model IC-901-IDD) mounted behind the center response key could display red and green homogeneous fields, a small white dot on a black background, and three white vertical and three white horizontal stripes also on black backgrounds (BRS/LVE Pattern No. 692). The projectors behind the left and right keys could display blue, yellow, and white homogeneous fields, and a white open triangle on a black background (BRS/LVE Pattern No. 696). A single IBM-compatible 386 computer controlled stimulus presentations and recorded responding in both chambers via a custom-built interface.

Procedure

Preliminary training. Pigeons were trained initially to eat reliably from a raised and lit food hopper, after which the key-peck response to the white dot on the center key was shaped by the method of successive approximations. After key pecking was established, single pecks to the various stimuli that would later serve as sample or comparison stimuli were reinforced during a series of 60-trial sessions. The stimuli were presented either on the center key (if later serving as samples) or the left and right side keys (if later serving as comparisons), and appeared equally often in random order at their respective locations. Trials in each session were separated by a dark 10-s intertrial interval (ITI). The duration of food presentation was constant within a session but varied from 2 to 6 s across sessions in such a way as to maintain each pigeon's 80% body weight.

Next, pigeons learned to obtain food by pecking multiple times to vertical and horizontal lines on the center key. For pigeons in the Nondiff-Within and All-FR groups, the same FR requirement was in effect for both stimuli, with the FR value gradually increasing from 3 to 10 over successive sessions. A minimum of two sessions was conducted with FR 10. For pigeons in the Differential group, food was obtained by completing a DRL 3-s requirement for pecking one line stimulus and by completing a FR requirement for the other, counterbalanced across subjects. As in the other groups, the value of the FR was gradually increased to 10 over successive sessions with at least two sessions at its final value. For all groups, the vertical and horizontal lines each appeared 30 times in pseudorandom order in a session. Successive trials were separated by a 10-s ITI, the first 9 s of which was spent in darkness. The house light came on for the last 1 s of the ITI and remained on until the end of the reinforcement cycle. Reinforcement durations were adjusted daily as before. Group All-FR then underwent this same training procedure with red and green center-key stimuli.

The final phase of preliminary training for all groups consisted of two to four sessions containing an equal number of center-key presentations (20) of all four stimuli (vertical, horizontal, red, and green) in pseudorandom order. When the center-key stimulus was red or green, a single peck (Groups Differential or Nondiff-Within) or 10 pecks (Group All-FR) produced food reinforcement. When the center-key stimulus was vertical or horizontal, the DRL or FR contingency previously described for each group was in effect. All other procedural details were the same as before.

Many-to-one (MTO) matching acquisition. MTO matching began after the end of preliminary training. Each trial of MTO training began with one of four sample stimuli (vertical, horizontal, red, or green designated as S1 – S4 in Table 1) appearing on the center key. On line-sample trials, completing an FR 10 sample–response requirement to either vertical or horizontal (Groups Nondiff-Within or All-FR) or completing the DRL 3-s requirement to one vs. an FR 10 requirement to the other (Group Differential) turned off the sample stimulus and produced blue and yellow comparison alternatives on the adjacent side keys. On hue-sample trials, these comparisons were obtained by pecking once (CRF requirement—Groups Differential and Nondiff-Within) or 10 times (FR requirement—Group All-FR) to red or green. A single peck to either comparison turned off both and produced food or an equivalent timeout period with the house light off depending on whether the correct or incorrect comparison, respectively, was pecked. For all groups, pecking the blue comparison was the correct (reinforced) choice on vertical-sample (S1) and red-sample (S3) trials, whereas pecking the yellow comparison was correct on horizontal-sample (S2) and green-sample (S4) trials. The alternative choices on these trials were incorrect (nonreinforced).

Each 96-trial MTO training session had an equal number of the eight possible trial types (four samples x two left–right positions of the comparisons) randomly intermixed such that no one trial type occurred more than three times in a row. Successive matching trials were separated by a 10-s ITI, the first 9 s of which was spent in darkness. As before, the constant reinforcement duration used in each session was adjusted daily, as needed, for each bird so as to maintain its 80% body weight. Individual pigeons were trained on their respective MTO tasks until they met a criterion of 90% or better overall matching accuracy plus at least 87.5% accuracy with both line and hue samples on five of six consecutive sessions. Ten additional overtraining sessions then followed.

Reassignment training. Next, each pigeon learned to match the red (S3) and green (S4) samples to new comparison alternatives (the triangle and homogeneous white stimuli). Each 100-trial reassignment training session consisted of equal numbers of the four possible sample–comparison combinations (two samples x two left–right positions of the comparisons), randomly intermixed with the constraint that no combination occur more than three times in a row. Pigeons in Groups Differential and Nondiff-Within obtained the comparisons by pecking each hue sample once (CRF requirement), whereas pigeons in Group All-FR had to complete an FR 10 requirement for both red and green. The red or green sample on each trial went off as the triangle and white comparisons appeared (a 0-delay procedure). A single peck to either comparison then turned off both alternatives and produced food or an equivalent timeout period with the house light off depending on whether that choice was designated as correct or incorrect, respectively. For half of the pigeons in each group, pecking the triangle comparison on red-sample trials and pecking the white comparison on green-sample trials were correct (reinforced); for the remaining pigeons, the opposite sample–comparison relations were reinforced. Reassignment training was alternated with refresher training on each pigeon's respective MTO task and continued until matching accuracy in reassignment was at least 90% correct for five of six sessions. One pigeon in Group Nondiff-Within was temporarily placed on a correction procedure after 32 reassignment sessions in order to generate the requisite levels of performance. While on correction, a nonreinforced choice on any matching trial repeated that trial. Once criterion levels of performance were achieved with the correction procedure, the procedure was discontinued and reassignment training proceeded until criterion was again achieved. For 3 pigeons in Group Differential, the noncorrection performance criterion was relaxed because they were unable to maintain accuracies above 90% correct for five of six sessions. Nevertheless, they often exceeded 90% correct in a single session and were routinely above 85% correct. Their average accuracies for the five reassignment sessions preceding testing were 89.6%, 89.4%, and 89.4% correct, respectively.

Following the last reassignment session, pigeons received a single refresher session on MTO matching on the day prior to acquired equivalence testing.

Testing. During testing, pigeons matched the remaining two (S1 and S2) samples from MTO training (viz., the vertical and horizontal lines) to the triangle and white comparisons introduced during reassignment training. Pigeons obtained the comparisons on each matching trial either by completing a FR 10 sample–response requirement to both vertical and horizontal (Groups Nondiff-Within and All-FR) or by completing a DRL 3-s requirement to one line sample and a FR 10 requirement to the other (Group Differential), as per each pigeon's contingencies. For half of the pigeons in each group, the correct (reinforced) choice following each line sample was consistent with the acquired equivalence classes that potentially developed during MTO training. For instance, since the vertical (S1) and red (S3) samples occasioned the same reinforced choice in MTO matching [as did the horizontal (S2) and green (S4) samples], then the reinforced choice on vertical-sample test trials was the same choice that had been reinforced on red-sample trials in reassignment (and likewise for the horizontal-sample test trials.) For the other half of the pigeons in each group, the correct (reinforced) choices in testing were inconsistent with [Red, Vertical] and [Green, Horizontal] sample classes.

In each of the ten 100-trial test sessions, the four possible sample–comparison combinations occurred equally often in pseudorandom order with the restriction that no combination occur more than three times in a row. All other procedural details were identical to those for reassignment.

Statistical Analyses

Type I error rate for all statistical tests reported here and in the following experiment was set at .05 using the critical F values reported by Rodger (1975).

Results

Preliminary training established the expected response patterns to the stimuli that would later serve as samples in the matching tasks. By the end of preliminary training, pigeons rapidly pecked the stimuli with the FR requirement and, in Group Differential, exhibited a pattern of spaced responding to the stimulus with the DRL requirement. Across all groups and stimuli, the average percentage of interresponse times (IRTs) less than 1500 ms was 99.5% for the FR stimuli (range: 98.6 – 99.9%), and the percentage of IRTs greater than 1500 ms (Group Differential only) was 65.1% for the DRL stimulus (range: 40.6 – 93.8%).

Matching acquisition and baseline performances. Group All-FR reached criterion levels of accuracy sooner in MTO matching (13.8 sessions) than Group Differential (39.2 sessions) and Group Nondiff-Within (43.2 sessions), $F(2, 14) = 5.76$, which did not differ from one another, $F(2, 14) = 0.08$. Within their respective tasks, Group All-FR achieved criterion levels with equal rapidity on line- and hue-sample trials: 11.2 vs. 11.0 sessions, respectively, $F(1, 5) = 0.08$. By contrast, Group Differential learned to match accurately faster with the line than with the hue samples (13.7 vs. 39.2 sessions, respectively), $F(1, 5) = 23.29$, as did Group Nondiff-Within (17.2 vs. 42.2 sessions, respectively) although the latter difference was not statistically significant, $F(1, 4) = 3.26$. During reassignment, Group All-FR reached criterion levels of accuracy in fewer sessions (6.0) than either Group Differential (31.0) or Group Nondiff-Within (22.6), $F(2, 14) = 4.97$, which did not differ significantly from one another, $F(2, 14) = 0.57$.

Baseline performances prior to testing, however, were comparable. On the last MTO refresher session, average accuracies for

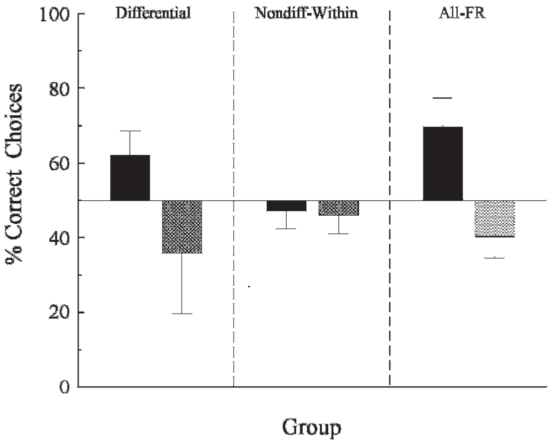

Fig. 1. Average percentages of correct choice on the first acquired equivalence transfer test for each group in Experiment 1 as a function of class-consistent (solid bars) vs. class-inconsistent (stippled bars) tests. Error bars represent 1 standard error of the mean (SEM).

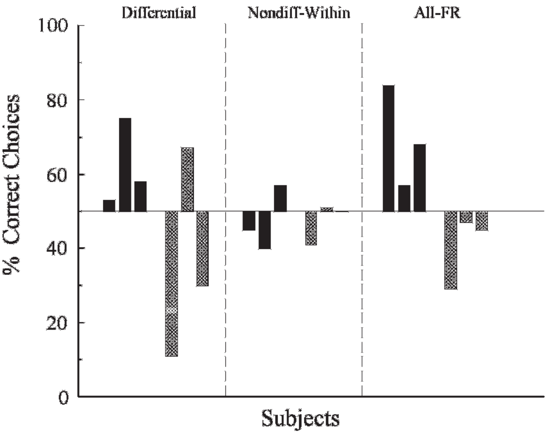

Fig. 2. Average percentages of correct choice for individual subjects by group in Experiment 1. Solid and stippled bars indicate subjects receiving class-consistent and class-inconsistent tests, respectively.

Groups Differential, Nondiff-Within, and All-FR were 95.7%, 96.5%, and 98.6%, respectively. Despite significantly higher accuracy for Group All-FR, $F(2, 14) = 4.33$, these differences were clearly quite small. Pretest MTO performances for pigeons assigned to the consistent and inconsistent test conditions were also comparable: 96.9% vs. 94.4% in Group Differential, $F(1, 4) = 1.44$, 98.3% vs. 99.0% in Group All-FR, $F(1, 4) = 0.57$, and 97.2% vs. 95.3% in Group Nondiff-Within, $F(1, 3) = 10.44$. Although the latter difference was significant, accuracies were nonetheless very high, so the difference was not a concern.

For the five reassignment sessions that immediately preceded testing, Group All-FR matched more accurately (95.2% correct) than Groups Differential (89.9%) and Nondiff-Within (92.3%), $F(2, 14) = 9.52$, which not differ from one another, $F(2, 14) = 2.28$. The difference was not unexpected because pigeons in Group All-FR pecked each hue sample 10 times, whereas those in the other groups pecked each hue sample only once. More importantly, accuracies within each group did not differ as a function of consistent vs. inconsistent test assignments, largest $F(1, 4) = 2.69$.

Testing. Figure 1 shows the average accuracies on the first test session for each group as function of the consistent vs. inconsistent test. Overall accuracy was above chance in the consistent condition and below chance in the inconsistent condition for Groups Differential and All-FR. For Group Nondiff-Within, accuracies were close to chance (50% correct) and, not surprisingly, did not differ significantly between consistent (47.3%) and inconsistent (46.0%) test conditions, $F(1, 3) = 0.03$. By contrast, accuracy was significantly higher in the consistent test (69.7%) than in the inconsistent test (40.3%) for Group All-FR, $F(1, 4) = 9.16$. The accuracy difference between test conditions for Group Differential (62% vs. 36%, respectively), however, was not significant, $F(1, 4) = 2.15$.

Individual-subject test data, shown in Figure 2, may help to explain the latter result. Two of the Group Differential birds tested with class-inconsistent relations matched well below chance levels on their first test session (11% and 30% accuracy, respectively), but the remaining bird matched above chance (67%).

Discussion

One result from this experiment is clearly in line with the hypothesis that acquired equivalence does not develop between sample stimuli that occasion the same reinforced choice if those samples are otherwise responded to differently. Specifically, pigeons in Group Nondiff-Within did not show the typical consistent–inconsistent difference in accuracy during testing that followed reassignment training with two of the four samples from

MTO matching. During this group's MTO training, pigeons pecked one common-choice sample 10 times but the other common-choice sample only once. This variation was apparently sufficient to preclude acquired equivalence given that sample equivalence was evident in Group All-FR. The latter group, in which pigeons responded identically to all samples, exhibited above-chance accuracy in a class-consistent test but below-chance accuracy in a class-inconsistent test (Urcuioli et al., 1989, Exp. 2; Urcuioli & Lionello-DeNolf, 2001; see also Grant & Spetch, 1994, and Wasserman et al., 1992).[1]

The test results from Group Differential, however, challenge our working hypothesis. Even though accuracies in the consistent and inconsistent conditions for this group did not differ significantly, substantial negative transfer was observed for 2 pigeons that received the inconsistent test. Although it might be tempting to dismiss their performances as due to nonequivalence-related factors given that first-session accuracy for the other inconsistent pigeon was above chance (67%), it is probably easier to dismiss the latter result. After all, even in the absence of acquired equivalence, pigeons that peck one sample on a DRL schedule and another on a FR schedule learn to match those samples to the comparison alternatives very quickly (Urcuioli & Honig, 1980), so the latter bird's above-chance performance might reflect especially rapid learning. From this perspective, the remaining 2 inconsistent birds matched well below chance despite the facilitative effect of differential sample responding on learning.

Furthermore, in contrast to Urcuioli et al. (2006), the results from Group Differential seem to suggest an acquired equivalence in which sample–response patterns are class members. But even assuming that this group's MTO training had produced acquired equivalence between samples occasioning a common choice, it is unclear exactly what some of the functional samples were. After all, vertical and horizontal center-key stimuli (S1 and S2 in Table 1) occasioned the pigeons' DRL and FR response patterns throughout MTO training and in testing. Thus, class members might be the vertical and horizontal lines themselves rather than the response patterns.

[1] First-session accuracy for one of the All-FR birds in the inconsistent condition was probably higher than it would have been had a computer failure not interrupted its first test session and required the session to be restarted. At the time of the failure (the 31st trial of a 100-trial session), this pigeon's accuracy was 30% correct.

Table 2

Schematic of the Many-to-One Contingencies in Experiment 2.

Differential	Nondiff-Within
S1 • DRL → C1+	S1 • FR → C1+
S2 • FR → C2+	S2 • FR → C2+
S3 • CRF → C1+	S3 • CRF → C1+
S4 • CRF → C2+	S4 • CRF → C2+
Within-Dimension	Between-Class
S1 • FR → C1+	S1 • FR → C1+
S2 • CRF → C2+	S2 • CRF → C2+
S3 • CRF → C1+	S3 • FR → C1+
S4 • FR → C2+	S4 • CRF → C2+

Note. S1–S4 represent sample stimuli; C1 and C2 represent comparison stimuli, (+) = reinforced comparison choice, DRL = differential-reinforcement-of-low-rates-of-responding schedule, FR = fixed ratio schedule, CRF = continuous reinforcement schedule. DRL and FR schedule parameters and nonreinforced comparison choices are not shown.

EXPERIMENT 2

The purpose of Experiment 2 was twofold. First, we wanted to replicate the test results obtained in Experiment 1 from the conditions in which pigeons pecked differently to samples that occasioned the same reinforced choice (viz., Groups Differential and Nondiff-Within). Second, we wanted to assess the effects of other across-sample variations in response requirements.

Table 2 shows the four sets of MTO contingencies used in this experiment. The top row shows the contingencies for the two replication conditions. The bottom row shows the contingencies for two other groups that learned the same MTO sample–comparison relations as Groups Differential and Nondiff-Within, but with different variations in sample–response requirements. For the Within-Dimension group, pigeons were required to complete different requirements to the two samples within each visual dimension (viz., lines and hue) in order to obtain the comparisons. Specifically, they had to peck one line-orientation sample (S1) 10 times (FR) but the other line-orientation sample (S2) only once (CRF). Likewise, they had to peck one hue sample (S4) on the FR schedule and the other hue sample (S3) on a CRF schedule. As for Group Nondiff-Within, different response requirements were in effect for samples occasioning the same reinforced choices (viz., FR for S1 but CRF for S3, and FR for S4 but CRF for S2), and the same requirement was in effect for samples occasioning different reinforced choices (viz., FR to both S1 and S4; CRF to both S2 and S3).

By contrast, pigeons in the Between-Class group were required to complete the same requirement to samples occasioning the same reinforced choice and to complete different requirements to samples occasioning different reinforced choices. Specifically, pigeons pecked 10 times (FR) to both samples (S1 and S3) for which C1 was the reinforced comparison and once (CRF) to both samples (S2 and S4) for which C2 was the reinforced comparison. If ''sample class'' is defined in terms of common choice, the variation in response requirements for these pigeons is entirely between classes.

Using the same transfer-of-control assay of acquired equivalence as in Experiment 1, we predicted especially strong transfer effects in Group Between-Class because the sample behavior arising from their response requirements provided a valid cue for choice. On the other hand, we predicted that there would be no transfer effects indicative of acquired sample equivalence in Groups Nondiff-Within and Within-Dimension because these pigeons pecked differently to the samples within each common-choice class and identically to the samples between classes. Our working hypothesis also predicts no acquired sample equivalence in Group Differential, although the individual results observed in this group in Experiment 1 tempered our confidence in this prediction.

Method

Subjects and Apparatus

Twenty-four White Carneaux retired breeders obtained from the same supplier used for Experiment 1 participated in this experiment. Fourteen were experimentally naïve; the other 10 had participated in studies of ambiguous-cue discrimination learning (Urcuioli & Michalek, 2007). Prior to the start of the experiment, pigeons were randomly divided into four groups (cf. Table 2) with the constraint that 2 or 3 experienced pigeons be in each group.

The experimental chambers and control equipment were the same as in Experiment 1 except that the side-key stimulus projectors could now display red and green homogeneous fields, and a white open circle and a white ''X'' on black backgrounds (BRS/LVE Pattern No. 696).

Procedure

Preliminary training. Experimentally naïve pigeons were trained initially to eat from a raised and lit food hopper, after which the key-peck response to the white dot on the center key was shaped by the method of successive approximations. Subsequently, they and the experienced pigeons were trained over seven sessions to peck all of the stimuli later used as samples or comparisons in the matching tasks. Those serving as samples appeared on the center key and those serving as comparisons appeared on the left and right side keys. A single peck to each displayed stimulus was reinforced with food. All other details of these sessions were the same as in Experiment 1.

Next, all pigeons received training with red and green center-key (sample) stimuli presented equally often in each of six 60-trial sessions. For the Differential and Nondiff-Within groups, food was contingent on a single peck (CRF) to either hue. For the Within-Dimension and Between-Class groups, food was contingent on a single peck to one hue and completion of a FR requirement to the other hue, partially counterbalanced across birds. The value of the FR was raised from 2 to 10 across sessions such that the terminal FR 10 schedule was in effect for the last two sessions. All other details were identical to the corresponding sessions in Experiment 1.

The last six preliminary training sessions were conducted with vertical and horizontal center-key lines. For Group Differential, completing a DRL 3-s requirement to one line and an FR requirement to the other produced food, counterbalanced across birds. For Group Nondiff-Within, pecking both lines on the same FR schedule produced food. For Group Within-Dimension, food was contingent on a single peck to one line and on completion of a FR requirement to the other line with the restriction that the response requirements for vertical (S1) and horizontal (S2) be the same as for green (S4) and red (S3), respectively (cf. Table 2). Group Between-Class was treated like Group Within-Dimension except that the response requirements for vertical (S1) and horizontal (S2) matched those for red (S3) and green (S4), respectively. For all groups, the value of the FR was gradually raised across sessions in the manner previously described. All other procedural details were the same as before.

Many-to-one (MTO) matching acquisition. MTO acquisition immediately followed preliminary training. Each matching trial began with either vertical, horizontal, red, or green (S1 – S4 in Table 2) as the center-key sample. For each sample stimulus, completing the response requirement in effect at the end of preliminary training immediately turned off the sample and produced red and green comparison stimuli (C1 and C2 in Table 2) on the adjacent side keys[2]. For all pigeons, a single peck to the red (C1) comparison following the vertical (S1) or red (S3) sample was reinforced (+), as was a single peck to the green (C2) comparison following the horizontal (S2) or green (S4) sample. Pecking the alternative comparison on these trials was nonreinforced and immediately turned off the house light for a period equal to the reinforcement duration for that session. All other details of these 96-trial sessions were identical to the corresponding MTO sessions in Experiment 1 including the same performance criterion as well as the 10 postcriterion overtraining sessions.

Reassignment training. During reassignment training, pigeons in all four groups learned to match the red (S3) and green (S4) samples to new (''X'' and circle) comparison stimuli. The sample–response requirements for red and green were identical to those for these samples during each group's MTO matching task. Thus, a single peck (CRF) to either red or green produced the comparisons in Groups Differential and Nondiff-Within, whereas a single peck to one hue vs. completion of a FR 10 schedule produced the comparisons in Groups Within-Dimension and Between-Class. All other details, including daily alternation of the reassignment sessions with refresher training on each group's respective MTO matching task, were identical to those in Experiment 1. A single MTO refresher session at criterion levels of accuracy preceded testing for each pigeon.

Testing. During testing, pigeons matched the remaining vertical-line (S1) and horizontal-line (S2) samples from MTO training to the ''X'' and circle comparisons from reassignment training. The sample–response requirements for each pigeon were identical to those in effect during MTO matching. Thus, to obtain the comparisons, pigeons completed either FR 10 sample–response requirement to both line samples (Group Nondiff-Within), a DRL 3-s requirement to one line and a FR 10 requirement to the other line (Group Differential), or a FR 10 requirement to one and a single-peck (CRF) requirement to the other (Groups Within-Dimension and Between-Class). As in Experiment 1, each group was divided into consistent and inconsistent subgroups for testing. In the consistent test conditions, the reinforced ''X'' vs. ''C'' comparison choice on each line-sample trial was identical to the reinforced choice after each hue sample with which the line shared a common choice association in MTO training. In the inconsistent test conditions, each reinforced line-sample choice was the opposite of the reinforced choice following the hue sample with which the line shared a common choice association in MTO training.

Procedural details for the test sessions were identical to those in Experiment 1.

Results

Once again, preliminary training established schedule-appropriate performances to the stimuli that would later serve as samples in MTO matching—rapid, uninterrupted pecking to the stimuli associated with the FR requirements (all groups) and spaced pecking to the stimulus associated with the DRL requirement (Group Differential only). For sessions with the FR 10 requirement, the percentage of IRTs less than 1500 ms to the FR stimuli, averaged across groups and stimuli, was 98.9% (range: 97.5 – 99.7%). The average percentage of IRTs greater than 1500 ms to the DRL stimulus on the last two preliminary training sessions for Group Differential was 61.2% (range: 38.6 – 90.7%).

[2] Red and green comparisons were used in this experiment instead of the blue and yellow comparisons used in Experiment 1 to avoid any possible carryover effects from the prior experimental histories of the experienced (non-naïve) pigeons.

Matching acquisition and baseline performances. Group Between-Class required the fewest training sessions to reach criterion (8.3) in MTO matching, Groups Differential and Nondiff-Within required the most sessions (37.5 and 37.7, respectively), and Group Within-Dimension an intermediate number (21.2). Post-hoc contrasts (Rodger, 1975) showed that sessions-to-criterion did not differ between the Differential and Nondiff-Within groups, $F(3, 20) = 0.00$, but this was significantly greater than for the Between-Class group, $F(3, 20) = 17.98$. Group Within-Dimension fell between these two extremes, $F(3, 20) = 1.04$. Matching acquisition with the line and hue samples was equally rapid in the Within-Dimension and Between-Class groups [Fs$(1, 5) = 0.89$ and 2.50, respectively], but was more rapid with lines than with hues in the Differential and Nondiff-Within groups [Fs$(1, 5) = 55.24$ and 7.25, respectively]. For reassignment training, Groups Within-Dimension and Between-Class reached criterion in 8.8 and 12.7 sessions, respectively [$F(3, 20) = 0.08$], compared to 36.0 and 31.7 sessions for Groups Differential and Nondiff-Within, respectively [$F(3, 20) = 0.07$]. The difference in rate of acquisition between the former and latter two groups was significant, $F(3, 20) = 4.83$.

Despite the various acquisition differences, baseline performances prior to testing were comparable across groups. On the last MTO refresher, mean accuracies ranged from 94.8% to 97.2% and did not differ significantly between groups, $F(3, 20) = 2.04$. Likewise, within-group accuracies for pigeons assigned to the consistent and inconsistent test conditions were also comparable: 95.1% vs. 96.2% for Group Differential, 98.3% vs. 95.8% for Group Nondiff-Within, 94.4% vs. 95.1% for Group Within-Dimension, and 96.5% vs. 97.9% for Group Between-Class. Only the difference for Group Nondiff-Within approached significance, $F(1, 4) = 7.04$, $p = .06$, but even here accuracies were uniformly high. Matching accuracy on the last reassignment session ranged from 92.2% – 96.3% across groups and did not differ significantly between them, $F(3, 20) = 1.97$. Moreover, they also did not differ significantly within each group as a function of consistent vs. inconsistent test assignments, largest $F(1, 4) = 0.82$.

Testing. Figure 3 shows each group's average accuracy on the first test session as a function of consistent and inconsistent testing (black and stippled bars, respectively). Figure 4 shows the individual subject data for each group.

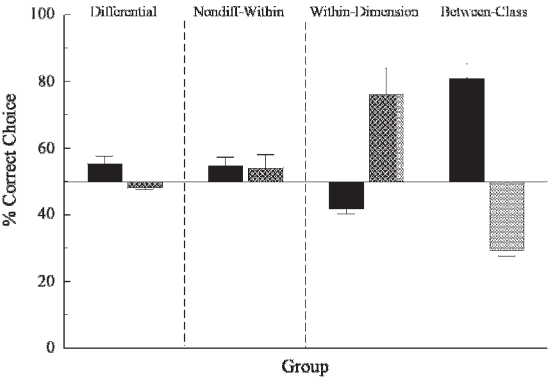

Fig. 3. Average percentages of correct choice on the first acquired equivalence transfer test for each group in Experiment 2 as a function of class-consistent (solid bars) vs. class-inconsistent (stippled bars) tests. Error bars represent 1 SEM.

The test data exhibit some interesting features. First, as in Experiment 1, performances in Group Nondiff-Within did not differ between class-consistent and class-inconsistent tests: 54.7% vs. 54.0% correct, respectively, $F(1, 4) = .02$. Second, the corresponding difference for Group Differential (55.3% vs. 48.3% correct, respectively), although numerically much smaller than in Experiment 1 (cf. Figure 1), was statistically significant here, $F(1, 4) = 7.87$, given the performance consistency within each test condition (cf. Figure 4). Third, as predicted, the Between-Class group showed a large accuracy difference across test conditions: 81.0% vs. 24.2%, respectively, $F(1, 4) = 112.27$. Finally, contrary to hypothesis, there was a significant test condition difference in Group Within-Dimension which was due to lower first-session accuracies in the consistent than in the inconsistent condition: 42.0% vs. 76.0% correct, respectively, $F(1, 4) = 16.67$.

Considering that the matching contingencies for Group Differential here and in Experiment 1 were virtually identical, and likewise for Group Nondiff-Within, and that these two MTO training conditions were of particular interest to our working hypothesis, we combined the test results from each group across experiments for additional analysis. Figure 5 plots the combined data for the first

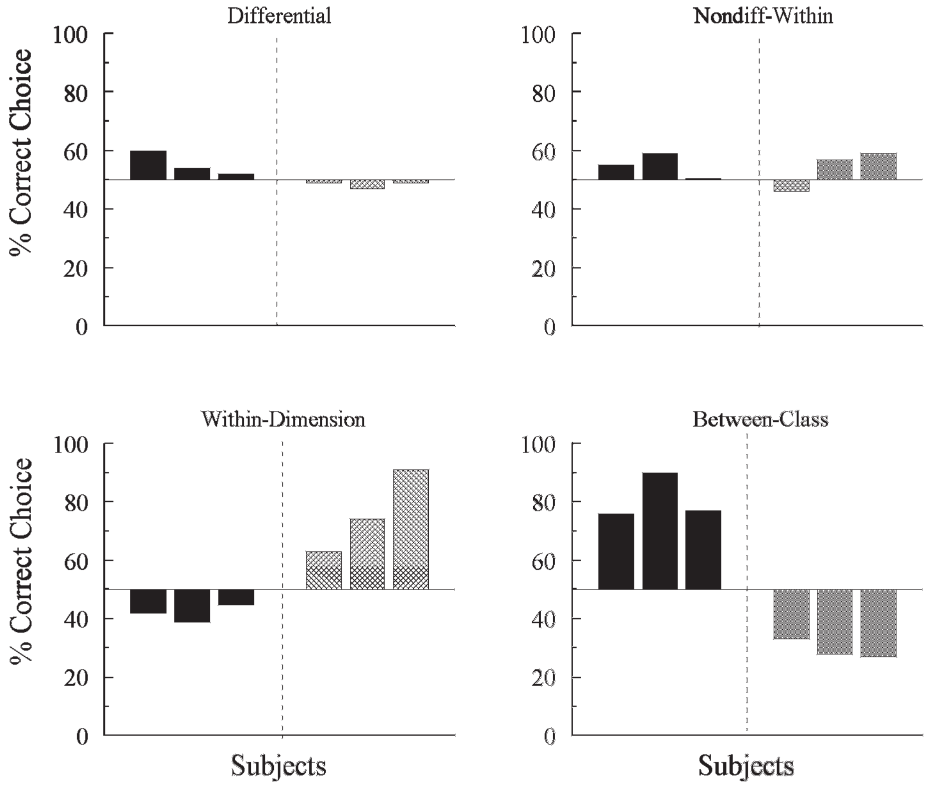

Fig. 4. Average percentages of correct choice for individual subjects by group in Experiment 2. Solid and stippled bars indicate subjects receiving class-consistent and class-inconsistent tests, respectively.

five test sessions. For the Differential condition, accuracy was higher overall in the consistent than in the inconsistent test. However, ANOVA showed no significant test-condition difference either on Day 1 testing or averaged over test sessions, *F*s(1, 10) = 3.68 and 3.56, respectively. The interaction between Test Condition and Test Session was also not significant, *F*(4, 40) = 1.00. For the Nondiff-Within condition, accuracies in the two test conditions were virtually indistinguishable. Not surprisingly, there was no significant effect of test condition on Day 1 accuracies or averaged over test sessions, *F*s(1, 9) = .00 and .04, respectively, and no significant Test Condition x Test Session interaction, *F*(4, 36) = .60.

Discussion

This experiment replicated the results from Group Nondiff-Within of Experiment 1 by showing that acquired sample equivalence does not develop in MTO matching if pigeons respond (a) differently to the samples occasioning the same reinforced choice and (b) identically to samples occasioning different reinforced choices. This conclusion is reinforced by analysis of the combined test results from this treatment condition across Experiments 1 and 2.

The Day 1 test data from Group Differential in this experiment indicated acquired sample equivalence despite differences in responding to the common-choice samples using DRL vs. FR sample–response requirements (cf. Urcuioli et al. 2006). Nonetheless, when the results from this condition were combined across experiments, statistical analyses indicated no acquired equivalence despite a numerical test-condition difference in the proper direction. Perhaps the best that can be said about Group Differential is that the results lack the sort of subject-to-subject consistency that would make a firm conclusion possible.

By contrast, the results from Group Within-Dimension not only showed an unambiguous

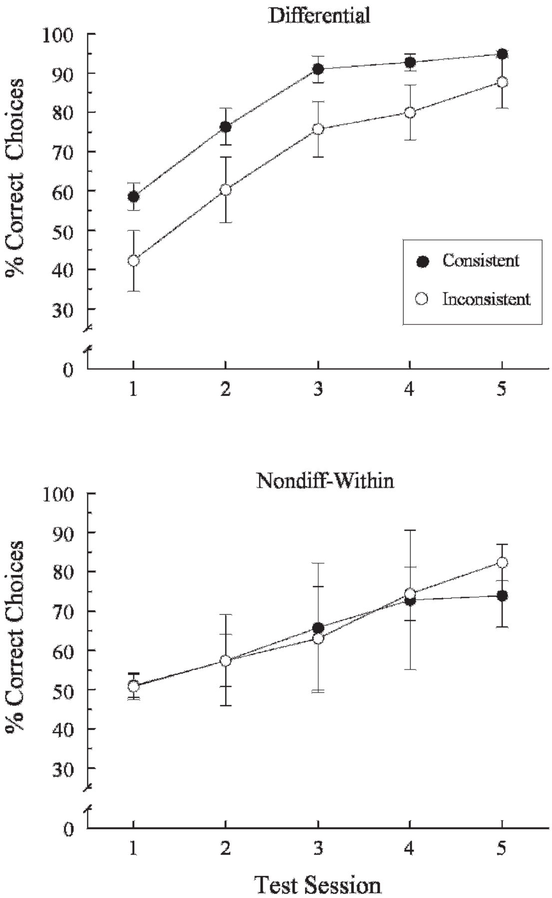

Fig. 5. Average percentages of correct choice for Groups Differential and Nondiff-Within in Experiments 1 and 2 combined over five successive transfer-test sessions. Filled and open symbols indicate class-consistent and class-inconsistent test, respectively. Error bars represent ±1 SEM.

test-condition difference that was contrary to prediction, but the difference itself was precisely the opposite of that predicted by acquired sample equivalence. In other words, accuracy in the class-consistent condition was lower than in class-inconsistent condition, rather than vice versa (e.g., Urcuioli et al., 1989). Closer examination of the reassignment and test contingencies for this group (see Table 3), however, reveals the likely explanation for this odd finding.

During reassignment training for Group Within-Dimension, the pigeons' sample–response patterns (i.e., CRF vs. FR) provided a valid cue for choosing between the C3 and C4 comparisons. Indeed, conditional stimulus control by such differential sample responding is well established in the literature (Urcuioli & Honig, 1980; see also Fetterman & MacEwen, 2003; Hogan, Zentall, & Pace, 1983; Lydersen & Perkins, 1974). If such control did develop in this group during reassignment training, it is likely to have continued in testing, resulting in a preference for the C4 comparison on S1 test trials and for the C3 comparison on S2 test trials (as underlined). The net effect of this would be above-chance accuracy in the inconsistent condition and below-chance accuracy in the consistent condition, just as observed.

Interestingly, the apparent control by CRF and FR responding during reassignment developed despite the fact that these response patterns had been *un*correlated with the reinforced choices (C1 and C2) during MTO training. If pigeons had to rely on the visual characteristics of the samples to perform accurately in MTO matching, why didn't those samples exert dominant conditional control during reassignment? Stated otherwise, shouldn't the already established sample cue from MTO training block conditional control by a CRF vs. FR cue during reassignment (cf. Kamin, 1969; Haggbloom, 1981; vom Saal & Jenkins, 1970)? The answer is "no." Unlike a blocking procedure, the choices "signaled" by the sample and sample–response cues during reassignment training (C3 vs. C4) differed from those "signaled" by the sample cue in MTO matching (C1 vs. C2). This change should promote unblocking (e.g., Dickinson, Hall, & Mackintosh, 1976)—in other words, it should permit the added CRF vs. FR cue in reassignment to acquire substantial control over choice.

Control by a CRF vs. FR cue can also explain the test results from Group Between-Class. These two schedules were correlated not only with the C3 vs. C4 choices during reassignment but also with the C1 vs. C2 choices during MTO training (cf. Table 2). In other words, throughout training, the Between-Class pigeons could base their comparison choice on whether they pecked the sample stimulus once or 10 times. The same was true in testing. Thus, acquired sample equivalence is not necessary to explain the above-chance accuracy in the consistent test condition and below-chance accuracy in the inconsistent test condition for Group Between-Class. If acquired equivalence had contributed to their

Table 3

Schematic of Training and Testing for Group Within-Dimension in Experiment 2.

Training		
Many-to-one	Reassignment	Testing
S1 • FR → C1+		
S2 • CRF → C2+	S3 • CRF → C3+	S1 • FR → C3 vs. $\underline{\text{C4}}$
S3 • CRF → C1+	S4 • FR → C4+	S4 • CRF → $\underline{\text{C3}}$ vs. C4
S4 • FR → C2+		

Note. S1–S4 represent sample stimuli; C1-C4 represent comparison stimuli, (+) = reinforced comparison choice, FR = fixed ratio schedule, CRF = continuous reinforcement schedule. FR parameters and nonreinforced comparison choices are not shown. Underlining of C4 and C3 indicates comparison choices predicted during Testing if these choices had been cued by the CRF and FR sample–response patterns during Reassignment training.

test performances, there should be a larger absolute accuracy difference between consistent vs. inconsistent test conditions for this group than for Group Within-Dimension. Although this was true numerically (e.g., 57% vs. 34%, respectively, on the first test session), it was not statistically significant in ANOVA, $F(1, 8) = 0.63$. Likewise, when all test sessions are considered, the Group x Test Condition interaction was not significant[3], $F(1, 8) = 2.67$, nor was the Group x Test Condition x Test Session interaction, $F(9, 72) = 0.69$.

GENERAL DISCUSSION

The two experiments reported here clearly demonstrate that transfer of matching performances to derived sample–comparison relations following MTO training depends upon sample–response requirements. When those requirements are the same for all sample stimuli (Group All-FR, Experiment 1), transfer indicative of acquired equivalence between samples that have occasioned the same reinforced choice is observed. Transfer is also observed when pigeons respond similarly to samples occasioning the same choice, but differently to samples occasioning different choices (Group Between-Class, Experiment 2). However, as just explained, this latter finding probably reflects conditional control by the pigeons' sample-specific behavior (cf. Urcuioli & Honig, 1980) and need not appeal to acquired equivalence between samples by virtue of their common choice association in MTO training.

Overt response mediation as a possible explanation for transfer in acquired equivalence studies has also been an issue in demonstrations of the transfer observed between stimuli that signal a common reinforcing outcome (cf. Urcuioli, 2005). For example, Astley and Wasserman (1999, 2001) found that stimuli signaling a common delay to reinforcement or a common amount of food reinforcement were interchangeable with one another in other contexts. In other words, after a new behavioral (i.e., choice) function was explicitly conditioned to one stimulus in each outcome class, this function immediately generalized to the other stimulus in the class, resulting in transfer performances indicative of acquired equivalence. However, because pigeons responded at different rates to the stimuli in each outcome class (viz., at higher rates to stimuli signaling a large amount of, or a short delay to, food reinforcement), the transfer results might reflect acquisition of stimulus control over performances by the different response rates during reassignment (see also Urcuioli & DeMarse, 1994) given that those same performances were required in testing. On the other hand, subsequent research by Frank and Wasserman (2005b) indicates that such overt response mediation is not necessary for the observed transfer effects in these differential outcome paradigms.

In any event, the issue of overt response mediation here is confined solely to Groups Between-Class and Within-Class of Experiment 2. The former group was included in the design of Experiment 2 to show that across-sample variation in response requirements per

[3] For this analysis (and the one immediately following), the data from Group Within-Dimension were reorganized such that ''consistent'' and ''inconsistent'' had the same meaning as for Group Between-Class: namely, referring to the relation between the pigeons' FR vs. CRF sample behavior and the reinforced choices in testing vis-à-vis the relation in reassignment training.

se does not preclude transfer between samples. An important consideration is whether differential sample responding arising from those requirements provided and continues to provide a valid cue for choosing between the comparison alternatives appearing in testing (Urcuioli, 1985). For both these groups, that was the case, and their transfer results are explicable by this account.

The data of greater interest are those from Groups Differential and Nondiff-Within for which response-mediated transfer was not a possibility. In both groups, pigeons responded differently to samples that occasioned the same reinforced choice in MTO matching but similarly to (at least some of) the samples that occasioned different reinforced choices. For Group Nondiff-Within, the net effect of this variation was to nullify acquired sample equivalence that would otherwise occur (cf. Group All-FR in Experiment 1). Transfer to derived sample–comparison relations, the equivalence assay, was absent for these pigeons in Experiment 1 and in Experiment 2 and when the data from both experiments were combined. Similarly, analysis of the combined data for Group Differential points to the same conclusion—no acquired sample equivalence. However, in view of the individual-subject results in Experiment 1, and the significant test condition effect on Day 1 testing in Experiment 2, perhaps a more defensible claim is that the sample–response requirements for Group Differential weakened the effect of common choice associations on acquired sample equivalence.

Variation in sample–response requirements amounts to explicit discrimination training between those samples (Urcuioli & Callender, 1989). Furthermore, such discrimination training has long been thought to produce an acquired distinctiveness of cues (cf. Hall, 1991), resulting in facilitation of performance on an orthogonal discrimination involving the same cues (e.g., Lawrence, 1949; Reese, 1972; Urcuioli & Callender, 1989). The present experiments were not structured in a way that would permit a distinctiveness assessment. Nevertheless, it may be worthwhile to speculate about the possible contribution of sample distinctiveness to the lack of acquired sample equivalence in Group Nondiff-Within and Group Differential vis-à-vis evidence for such equivalence in Group All-FR.

First, note that Group All-FR did not receive explicit sample-discrimination training as part of its MTO training (see Table 1). Instead, these pigeons learned to peck all four samples nondifferentially to produce the comparison alternatives. Under these conditions, those samples would be distinctive, so to speak, only in terms of which comparison choice was reinforced following them. Combined with the fact that one choice was reinforced following each of two samples and the alternative choice was reinforced choice following the other two samples, these common sample–comparison relations ought to be a salient feature of the matching contingencies. But these very relations are at the heart of acquired sample equivalence.

Second, and in contrast, pigeons in Groups Differential and Nondiff-Within not only pecked differently to the samples but, more importantly perhaps, they pecked differently to the two samples occasioning the same reinforced comparison choice. Under these conditions, the common sample–comparison relations defining each sample class may have been less salient to the pigeon than the fact that they directly pecked at each class member differently. After all, when the sample was present on the center key, pecking at it was more immediate than the comparison choice they made after the sample went off.

Of course, this sort of analysis presupposes that the functional samples are simply the stimuli appearing on the center key (see, for example, McIlvane, Serna, Dube, & Stromer, 2000). But another possibility is that the functional samples may have been compounds consisting of the visual stimulus plus its associated sample–response pattern. Grouping together those compounds occasioning the same reinforced choice, the functional samples for Group Nondiff-Within would be: [V–FR, R–CRF] and [H–FR, G–CRF], where V = vertical, H = horizontal, R = red and G = green. For Group Differential, the classes would be: [V–DRL, R–CRF] and [H–FR, G–CRF]. This sort of class representation highlights the within-class differences and between-class similarities mentioned earlier. One difference between Groups Nondiff-Within and Group Differential is the greater between-class similarity for the former given that both FR and CRF appear in each sample class, whereas only the CRF requirement does so for the latter group. Perhaps this explains the somewhat different transfer results in these two groups.

One approach to identifying what the functional sample stimuli truly are in, say, Group Nondiff-Within would be to switch sample–response requirements following MTO acquisition and observe how this affects baseline accuracy, if at all. If each functional sample is visual plus response-pattern compound, switching the response pattern element should produce a drop in matching accuracy. Of course, shifting from an FR to a CRF requirement would also be expected to cause a drop if the functional samples were just the visual stimuli due to shorter viewing times (cf. Eckerman, Lanson, & Cumming, 1968; Sacks, Kamil, & Mack, 1972). However, a shift from a CRF to an FR requirement should enhance (or at least not disrupt) accuracy if viewing time is crucial. On the other hand, this particular shift should also cause a drop in accuracy if the functional samples are visual–response compounds instead.

Further research is obviously necessary to clarify this particular issue. Moreover, it would also be interesting to know if any variation in sample–response requirements that does not introduce the possibility of response mediation will inhibit acquired sample equivalence. For instance, would pigeons trained on MTO matching in which they peck each sample 10 times on some trials but only once on other trials (a mixed FR–CRF schedule) subsequently show transfer between the samples occasioning the same reinforced choice? Under these conditions, there are no within-class differences in sample responding (akin to the conditions for Group All-FR), so acquired sample equivalence would seem to be predicted. Likewise, the various samples are not distinctive from one another on the basis of their sample–response requirements (they are identical for all samples), although the across-trial variation in the requirements for each sample may be sufficiently salient to overshadow the common choice associations shared by pairs of samples (see Pearce & Redhead, 1993 for other disruptive effects of such task-irrelevant variation).

In any event, the message from these experiments is clear. The observing–response requirements for the sample stimuli in MTO matching, and the way in which those requirements vary across samples occasioning the same choice and across samples occasioning different choices, have a clear impact on acquired equivalence.

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